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Long-term electricity demand forecasting of Sumatera system based on electricity consumption intensity and Indonesia population projection 2010-2035

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Abstract

An important step in energy management especially in electricity planning is demand forecasting. A simple model is presented using LEAP (Long-range Energy Alternative Planning System) as a tool and Sumatera systems as a case study. It aims to be easy to understand and applicable. Electricity demand in household sector is calculated based on data of population, household size, electrification ratio and electricity intensity. On the other hand, electricity demand in non-household sector is calculated as a product of number of customers and its electricity intensity. The base year is 2010 and 2025 is the end of forecasting period. The result shows that electricity demand in Sumatera system would be increase more than seven times compared to base year value. A comparative study was also carried out.

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Keywords: electricity; demand forecasting; LEAP; Sumatera

1. Introduction

Energy has important role in the human life. All of human activities need energy. Based on the fuel type, electricity has been the most used after the oil [1]. One of many reasons because of the electricity does not produce emission when it used [2]. Other advantages of electricity are easy to transmitted, easy to use and a lot of devices on

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earth need electricity as power source. Electricity also related to economic sector [3]. In Indonesia, the Granger causality test shows the relationship between electricity consumption and economic growth [4].

The share of electricity reached 12.3% of national energy consumption in 2010 [5]. Based on the region, most of electricity power consumed in Java and Sumatera [6]. As an island that consumed large of electricity, Sumatera experienced power shortage. This is due to the high demand growth but is not accompanied by appropriate of supply [7]. Therefore, good electricity management including both demand and supply planning is required.

One of important part in electricity management is demand forecasting. Various methods have been developed such as the Markov model [8], fuzzy linear regression [9], PSO [10] and combination of existing methods [11]. Factors or variables that believed could affect the electricity demand are population, GDP, GDP per capita, intensity and etc [12]. Electricity demand forecasting can be classified into three time-range terms, that are short-term load forecasting (STLF), 1 day to 1 year for medium-term load forecasting (MTLF), and 1±10 years for long-term load forecasting (LTLF) [13].

In 2013, Indonesia government published the book of Indonesia Population projection 2010-2035. Based on references above, one of various factor could affect the electricity consumption is population growth. This means that electricity demand generally in Indonesia and especially in Sumatera increases along with population growth. According to the population projection, long-term electricity demand until 2035 could be estimated.

2. Sumatera system

Since the last few years, the electricity consumption in Indonesia has shown significant increase due to the growth in population and the rise of human living needs [14]. The increase of electricity consumption with no adequate supply will cause the energy system unbalance. In Sumatera, rolling black out is common due to significant energy deficit. The electricity consumers are experienced rolling black out for 2 to 3 hours or even 6 hours. The power outages cannot be avoided due to the peak load demand is higher than the power generation capacity. It causes a lot of problems to consumers particularly related to their productivity [15].

Before 2004, electricity service in Sumatera Island consisted of three largest systems, they were northern Sumatera (Sumbagut), middle Sumatera (Sumbagteng) and southern Sumatera (Sumbagsel). After that year, the middle and southern were connected and named Southern-middle Sumatera (Sumbagtengsel). Later, they are united into Sumatera system since 2007. The Sumatera system covers eight provinces: NAD, North Sumatera, West Sumatera, Riau, Jambi, South Sumatera, Bengkulu and Lampung. It services four main sectors of customer. They are household, industry, commercial and public. The customer numbers of every sector are presented by Table 1, while Table 2 presents the electricity consumption in Sumatera system.

Fig. 1. Map of Sumatera and its electricity system.

Table 1. Number of electricity customer in Sumatera system [7].

Sector	Number of customer			
	2009	2010	2011	2012
Household	6646361	7054562	7885962	8580592
Industry	5624	5698	5869	6116
Commercial	342412	366004	386531	431797
Public	193264	205907	222038	238067

Table 2. Electricity consumption in Sumatera system [7].

Sector	Electricity consumption (GWh)			
	2009	2010	2011	2012
Household	8521.52	9844.23	11332.80	12815.89
Industry	3518.15	3681.51	3940.57	4325.76
Commercial	3210.88	3557.70	3648.29	3835.40
Public	1576.50	1732.22	1836.97	2015.84

3. Methodology

3.1. Modeling tool

The LEAP (Long-range Energy Alternative Planning) is an integrated energy modeling tool developed at Stockholm Environment Institute (SEI). LEAP is widely used for energy policy analysis and climate change mitigation. It has been used in more than 190 countries worldwide. LEAP model based on accounting with flexibility and a wide range of expertise. It can be used to track energy demand, transformation and resources. Various energy systems might be modeled. It because of LEAP is not a model of particular energy system.

In addition, LEAP also has the ability to support some of different modeling methodologies. For example on the demand side can be used to assist bottom-up, end-use and top-down macroeconomic modeling. On the supply side, LEAP provides a range of accounting, simulation and optimization methodologies that are powerful enough for modeling electric sector generation and capacity expansion planning, but which are also sufficiently flexible and transparent to allow LEAP to easily incorporate data and results from other more specialized models. Another key benefit of LEAP is its low initial data requirements [16].

3.2. Final electricity demand analysis

Final electricity demand analysis is calculated for each year and branch (sector). Electricity demand is calculated as a product of total activity and electricity intensity [16].

$$ED_{b,s,t} = TA_{b,s,t} . EI_{b,s,t} \tag{1}$$

where *ED* is electricity demand, *TA* is total activity, *EI* is electricity intensity, *b* is branch (sector of customer), *s* is scenario and *t* is time (year). In the final electricity demand analysis, energy intensity at device level can specified as amount of fuel used per unit of activity. In the other word, electricity intensity can be calculated from electricity consumption and number of customer (as total activity) data.

$$EI_{b,t} = \frac{EC_{b,t}}{TC_{b,t}} \; EI_{b,t} = \frac{EC_{b,t}}{TC_{b,t}} \tag{2}$$

where *EI* is electricity intensity, *EC* is electricity consumption, *TC* is total customer number, *b* is branch (sector) and *t* is year.

3.3. Forecasting method

The electricity demand forecasting in this study is calculated by very simple method. For household sector, electricity demand is calculated as product of customer number and its intensity. The number of customer and electricity intensity is projected to obtain customer numbers for the years after. Specific to household sector, the number of customer is projected based on population, household size (family member) and electrification ratio.

$$TC_{h,s,t} = \frac{P_{s,t}}{HS_{s,t}} . ER_{s,t} \tag{3}$$

where TC_h is total customer in household sector, *P* is population, *HS* is average of household member (household size) and *ER* is electrification ratio. Electrification ratio here is similar to electrification level that means percentage of households with electricity. Electrification ratio is different to electrification rate. Base on Equation (3), factors to estimate the electricity demand are population, household size, electrification ratio, and electricity intensity.

$$ED_{h,s,t} = \frac{P_{s,t}}{HS_{s,t}}.ER_{s,t}.EI_{h,s,t} \tag{4}$$

where ED_h is electricity demand in household sector. EI_h is electricity intensity in household sector. P, HS, ER, s and t are as described above. So the electricity demand forecasting for household sector can be calculated by projecting population, household size, electrification ratio, and electricity intensity.

Electricity demand for non-household sector is calculated simpler than household sector. There are only two factors used in this method. They are customer number and electricity intensity. Therefore, the electricity demand forecasting for non-household sector can be calculated by projecting the number of customer and its electricity intensity.

$$ED_{i,s,t} = TC_{i,s,t}.EI_{i,s,t} \tag{5}$$

$$ED_{c,s,t} = TC_{c,s,t}.EI_{c,s,t} \tag{6}$$

$$ED_{p,s,t} = TC_{p,s,t}.EI_{p,s,t} \tag{7}$$

where ED is electricity demand while i, c, and p describe branch or sector of industry, commercial and public.

4. Scenario development

In this study, scenario starts from 2010 as the base year. Population number in the future is based on Indonesia Population Projection 2010-2035 published by Indonesia government. Household size calculated from population divided by household number in 2010 and not expected to change due to lack of data. Electrification ratio in 2010 is 67.11%, expected to increase to 99.9% in 2020 and 100% in 2025 according to government target. Household electricity intensity growth rate is assumed to be 5.25% per year.

Non-household sector scenario developed according to number of customers and electricity intensity projection. Customer of industry sector is expected to increase 2.92% every year while its intensity grows 4.35% per year. Customer of commercial and public expected to increase 8.7% and 7.73% while its intensity growth rate are assumed to be 0.38% and 1.27%.

Table 3. Population projection in Sumatera system [17].

Province	Population number (000 persons)					
	2010	2015	2020	2025	2030	2035
NAD	4,523.1	5,002.0	5,459.9	5,870.0	6,227.6	6,541.4
North Sumatera	13,028.7	13,937.8	14,703.5	15,311.2	15,763.7	16,073.4
West Sumatera	4,865.3	5,196.3	5,498.8	5,757.8	5,968.3	6,130.4
Riau	5,574.9	6,344.4	7,128.3	7,898.5	8,643.3	9,363.0
Jambi	3,107.6	3,402.1	3,677.9	3,926.6	4,142.3	4,322.9
South Sumatera	7,481,6	8,052.3	8,567.9	9,000.4	9,345.2	9,610.7
Bengkulu	1,722.1	1,874.9	2,019.8	2,150.5	2,264.3	2,360.6
Lampung	7,634.0	8,117.3	8,521.2	8,824.6	9,026.2	9,136.1
Total	47,937.3	51,927.1	55,577.3	58,739.6	61,380.9	63,538.5

Table 4. Expected value in household size and electrification ratio.

Description	2010	2020	2025
Household size (persons per household)	4.16	4.16	4.16
Electrification ratio (%)	67.11	99.9	100.0

Table 5. Scenario for non-household sector.

Sector	Customer		Electricity intensity	
	2010 (Customer)	Growth rate (%)	2010 (GWh/customer)	Growth rate (%)
Industry	5698	2.92	0,646105651	4.35
Commercial	366004	8.7	0,009720386	0.38
Public	205907	7.73	0,008412633	1.27

5. Results and discussion

Results of electricity demand forecasting are presented in Table 6. The scenario shows that total electricity demand of Sumatera system in the end of forecasting period would increases more than seven times compared to the base year. Household electricity demand would increases from 10,790 GWh in 2010 to 76,596 GWh in 2035. Industry sector has electricity demand increasing from 3,682 GWh in the base year to 21,920 GWh in the end of period. Electricity demand in commercial would increases from 3,558 GWh to 31,484 GWh while in public the demand would be 15,277 GWh in 2035 increased from 1,732 GWh in 2010.

Table 6. Electricity demand in Sumatera system 2010-2035.

Sector	Electricity demand (GWh)					
	2010	2015	2020	2025	2030	2035
Household	10,790	18,785	31,067	42,450	57,292	76,596
Industry	3,682	5,260	7,515	10,738	15,342	21,920
Commercial	3,558	5,502	8,510	13,162	20,357	31,484
Public	1,732	2,677	4,138	6,395	9,884	15,277
Total	19,761	32,225	51,231	72,745	102,875	145,277

A comparative study of the forecasting result can be done in this paper. The results can be compared to electricity demand forecasting by the state electricity company (PT PLN) in 2013. PT PLN held electricity demand forecasting annually as part of RUPTL compilation. Latest document was published in 2013 named RUPTL 2013-2022. Objective of the RUPTL is to provide references and guidance for development of electricity infrastructure. By following that references and guidance, efforts to supply electricity needs should be efficient and well-planned. Targets intended to be achieved within ten years ahead.

Electricity demand forecasting in RUPTL calculated using a load projection model named “Simple-E”. This model uses regression method based on historical data of power sales, installed power, number of customers, economic growth and population. Then, choose independent variables that have significant role (strong correlation) to the electricity demand. The variables are economic growth and population. To accommodate waiting lists of new customer application, the installed power set as a variable. The “Simple-E” has a facility to find out level of accuracy of the model such as level of correlation and statistical tests. They also use WASP (Wien Automatic System Planning) to do simulation and optimization.

The result of comparative study is presented in Fig.1. Electricity demand as being resulted in this study are not differ too much compared to RUPTL results in 2013 until 2016. However, started from 2017 the results would have significant difference.

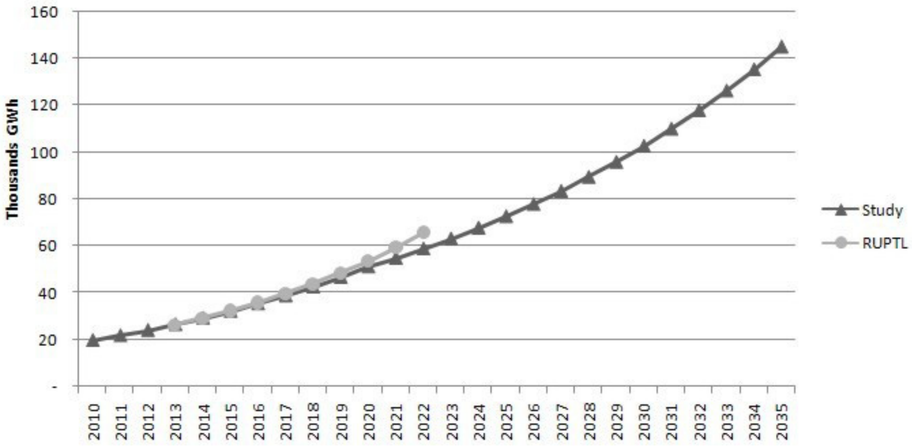

Fig. 2. Resulted electricity demand forecasting compared to RUPTL.

6. Conclusion

With the human needs raises every year, it would be followed by the increase of energy consumption. If not anticipated correctly, it would cause serious problems. Sumatera experienced in energy deficits that caused rolling black out up to six hours per day. By knowing estimated electricity demand, efforts to supply electricity needs should be efficient and well-planned. Therefore, electricity demand forecasting is required. This paper analyzes scenario of electricity demand projection from 2010 to 2035. Factors used in projection are population, household size, electrification ratio, number of customer and electricity intensity. This study use very simple method where each factors or variables are projected so that the electricity demand would be changed according to the value of projected variables. The results show that total electricity demand in the end of the period (2035) would be raises more than seven times compared to the base year (2010). It would be 145,277 GWh. Comparison with the RUPTL 2013-2022 published by PT PLN shows very close value in 2013-2016 periods. However, significant difference appears in the 2017-2022 periods. Electricity demand in 2022 is 6,809 GWh or 10.36% lower than RUPTL. The electricity demands are calculated using simple mathematical model. Some factors that can be used to estimate the household electricity demand are population, household size, electrification ratio and electricity intensity. In non-household sector, electricity demand can be calculated based on customer number and electricity intensity data. All factors are available in government publication ducuments. It can be concluded that the model is very simple, easy to understand and applicable.

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